APPENDIX 6-6

TASK 2.10 REVISED WATER BALANCE MODEL
TECHNICAL MEMORANDUM 2

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BLACK & VEATCH

TECHNICAL MEMORANDUM

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Task 2.10 Revised Water Balance Model Technical Memorandum 2

To: Distribution

From: Rafael Frias and Jeff Henson

1. OBJECTIVE

The purpose of EAA Reservoir A-1 is to capture Everglades Agricultural Area (EAA) basin runoff and releases from Lake Okeechobee. The facilities should be designed to improve the timing of environmental water supply deliveries to Stormwater Treatment Area (STA) 3/4 and the Water Conservation Areas (WCAs), reduce Lake Okeechobee regulatory releases to the estuaries, meet supplemental agricultural irrigation demands, and increase flood protection within the EAA. (Hornung et al.)

The overall objectives of the Water Balance Model (WBM) are as follows:

- To determine the quantity, duration, and timing of releases to the North New River Canal for irrigation needs
- To determine the quantity, duration, and timing of releases to the STA 3/4 Supply Canal for Everglades restoration needs
- To evaluate proposed pumping station location(s) and capacity(ies)
- To evaluate proposed gate location(s) and capacity (ies)

This technical memorandum summarizes the work conducted to develop the WBM including Model Configuration and Data Sources, Model Reliability and Initial Alternative Evaluation to demonstrate the suitability of the model for the analysis of alternatives for the design of the EAA A-1 reservoir.

2. MODEL CONFIGURATION AND DATA SOURCES

2.1 Model Construction

A water balance analysis is an important technique used to assess the components of a hydrologic and hydraulic system. A WBM was developed for the EAA Reservoir A-1 to analyze its storage capacity and operations on a daily basis (time step). The model was used to optimize the storage capacity of the reservoir, while evaluating the impacts on flows in the North New

River Canal, Miami Canal, Holey Land Distribution Canal, and the STA 3/4 Supply Canal. Figure 1 shows the location of the EAA Reservoir A-1 and canals. The WBM was also used to evaluate pumping facility locations and the distribution of releases from the reservoir for agricultural irrigation and environmental purposes.

The EAA A-1 WBM includes the following hydrologic components:

- Direct precipitation into the reservoir (P)
- Inflow through pumps and weirs from the canals (I)
- Outflow through weirs and culverts into the canals (O)
- Net evaporation from the reservoir surface (E)
- Seepage losses (S)
- Change in storage in the reservoir (ΔS)

The basic water balance equation is: $\Delta S = P + I - O - E - S$. This equation accounts for the change in storage in the reservoir based on inflows and outflows and was applied to the model on a daily basis.

2.2 Data Sources

The WBM is maintained in Microsoft Excel and incorporates formulas and Visual Basic programs to calculate changes in storage and stage over the period of record (POR). The POR extends for 36 years, from January 1, 1965 to December 31, 2000. Inflows and outflows used in the WBM were provided by the South Florida Water Management District (District) and the United States Army Corps of Engineers (USACE) Interagency Modeling Center (IMC), based on simulations using the South Florida Water Management Model (SFWMM).

The SFWMM provides simulated flows from both the North New River Canal, which runs parallel to the east side of the EAA Reservoir A-1 boundary, and the Miami Canal, located west of the reservoir boundary. Simulated flows from the North New River Canal and Miami Canal were based on future (year 2050) operating schedules for Lake Okeechobee, future land use projections, as well as the future release schedules for the STAs, as determined by District staff (Brion and Ali, 2002).

The SFWMM was set up to evaluate the water resources of the entire EAA basin. (Brion, 1999) The footprint of the reservoir, shown on Figure 2, has an area of 60,000 acres and a total usable storage of 360,000 acre-ft at a water depth of 6 ft. For comparison, the EAA Reservoir A-1, shown on Figure 3, is approximately 16,000 acres in size, with a total usable storage of approximately 199,000 acre-ft at a water depth of 12 ft.

IMC's simulated reservoir is divided into two equal compartments. Compartment 1 accepts runoff from the Miami Canal and North New River Canal basins and provides water mainly for agricultural irrigation needs. Irrigation needs are divided into the Miami Canal basin and the Hillsboro/North New River Canal basin. Compartment 2 accepts Lake Okeechobee excess inflow via both the Miami Canal and North New River Canal and provides water mainly for environmental needs. The environmental discharges from the model flow through STA 3/4 and into WCA-3A. During periods of zero environmental demands, the available flow in

Compartment 2 may be used to supplement irrigation needs. There is also an allowance for spillover from Compartment 1 to Compartment 2 through surge tanks.

Currently, the SFWMM used by IMC does not incorporate future improvements to the North New River Canal and Miami Canal. These improvements are currently being incorporated into the SFWMM and will be made available to Black & Veatch when completed. The proposed improvements include the expansion of the conveyance flow capacity of the North New River Canal and Miami Canal by 200 to 300 percent.

2.2.1 Inflows

Inflows included in the WBM consist of flows from the North New River Canal, Holey Land Distribution Canal, seepage collection canals, and precipitation. Input values for the canal flows are based on simulated values from the SFWMM. In the WBM, the available inflows from the North New River Canal into the EAA Reservoir A-1 have been set equal to the daily average simulated flows at pump station G-370. The Holey Land Distribution Canal branches from the Miami Canal and flows east connecting with the EAA Reservoir A-1 along the south half of the west side. In the WBM, available inflows from the Holey Land Distribution Canal into the EAA Reservoir A-1 have been set equal to the daily average flows at pump station G-372. G-372 simulated flow data were recently developed by the IMC and provided on March 3, 2005.

Some of the flow captured by seepage collection canals will be pumped back into the reservoir and serves as an inflow source in the WBM. Seepage return flow was estimated to be 175 cfs, based on information provided in the *Levee Optimization Report* (Jacobs/Montgomery Joint Venture, 2004). As part of a future Work Order, the WBM will be updated with the seepage results from the test cells program.

Mean daily precipitation data were obtained from the SFWMM on December 22, 2004 for the 10 cells that encompass the EAA Reservoir A-1 footprint. Inflow data was based on actual precipitation values for the POR, from January 1, 1965 to December 31, 2000. The average value of all 10 cells for each day in the POR was used as input data for the WBM. The daily average precipitation for the POR is shown on Figure 4.

2.2.2 Outflows

Outflows included in the WBM consist of evaporation, seepage, irrigation demands, environmental demands, and excess volume flows.

Evapotranspiration (ET) data were obtained from the SFWMM on December 22, 2004 for the 10 cells that encompass the EAA Reservoir A-1 footprint. Mean daily ET data were provided for the POR, from January 1, 1965 to December 31, 2000. The ET data used in the SFWMM were compared to historical direct evaporation data. Historical evaporation data were downloaded from DBHYDRO for the area in the vicinity of the EAA Reservoir A-1. The data provided by DBHYDRO is pan evaporation. A commonly accepted conversion of pan evaporation to actual evaporation is 70 percent of the pan evaporation equals actual evaporation. Using this conversion, a comparison of the ET data, used in the SFWMM, to actual evaporation data revealed little difference between the two values. Therefore, the average value of the ET data from all 10 cells was used as evaporation data for the WBM. The daily average evapotranspiration for the POR is shown on Figure 5.

Seepage at the dam was estimated to be 317 cfs, based on information from the *Levee Optimization Report* (Jacobs/Montgomery Joint Venture, 2004). This is the amount of flow that would seep beneath the reservoir on a daily basis as groundwater when storing water. As part of a future Work Order, the WBM will be updated with the seepage results from the test cells program.

Irrigation demands data were provided by the IMC on February 2, 2005 for the time period representing January 1, 1965 through December 31, 2000. The daily average irrigation demand to be met by the EAA Reservoir A-1 was assumed to be the Total Supplemental Demand in the EAA *(TSDMDEAA)*. This demand is equal to:

$$TSDMDEAA = TDMDEAA - TDMDMBYRF - TDMDMBLSTO$$

Where

TDMDEAA is the total irrigation demand in the EAA based on crop requirements.

TDMDMBYRF is the total irrigation demand met by rainfall.

TDMDMBLSTO is the total irrigation demand met by local storage.

The demands data are for a reservoir with a storage capacity of 360,000 acre-ft. The values were adjusted for a reservoir with a storage capacity of 199,000 acre-ft at a depth of 12 ft, approximately 55 percent of the total capacity. These were the irrigation demands set to be met by the EAA Reservoir A-1 and did not vary with additional changes in depth. Irrigation demands simulated by the SFWMM are shown on Figure 6.

Environmental demands were also provided by the IMC on February 2, 2005 for the time period representing January 1, 1965 through December 31, 2000. The environmental demand data included daily average simulated values to STA 3/4 from a reservoir with a storage capacity of 360,000 acre-ft. The environmental demands to be met by the reservoir were assumed to be:

$$Environmental\ Demands = WCS4S + EVBLSS$$

Where

WCS4S is the surface water only outflow for environmental water supply purposes from southern surge tank of the EAA reservoir to WCA-3A via STA 3/4.

EVBLSS is the subsurface water outflow down to 1.5 ft below land surface for environmental water supply purposes from southern surge tank in the EAA reservoir.

The values were adjusted for a reservoir with a storage capacity of 199,000 acre-ft at depth of 12 ft. These were the environmental demands set to be met by the EAA Reservoir A-1 and did not vary with additional changes in depth. Environmental demands simulated by the SFWMM are shown on Figure 7.

Excess volume flows are the flows discharged from the reservoir when full and inflows are greater than outflows. These flows need to be released to maintain the target maximum water surface elevation of the reservoir.

2.3 Reservoir Characteristics

The site boundary was determined from aerial photography based on the land acquired by the District for the proposed EAA Reservoir A-1 site. Two test cells are currently under construction, and field testing of these cells will determine a majority of the reservoir characteristics. Until the test cell results are available, some assumptions are necessary to develop a preliminary stage/area/storage relationship for input into the WBM. They are as follows:

- The outside toe of the reservoir embankment will begin approximately 200 ft in from the site boundary. This allows room for a canal to collect the seepage from the reservoir, a setback from the property line to the edge of the seepage canal, and greenspace between the outside toe of the embankment and the edge of the seepage canal

- A 25 ft tall embankment will be sufficient to meet the volume, freeboard, and wave run-up requirements

- 3:1 side slopes with a top width of 16 ft will meet the stability requirements for the reservoir embankment

These assumptions result in a total setback from the site boundary to the inside toe of the reservoir embankment of approximately 370 ft, as shown on Figure 8. The entire site boundary is approximately 17,600 acres, with the southern boundary being approximately 6.2 miles in length and the shortest distance from the north to the south boundary being approximately 6.4 miles (see Figure 3). The area defined by the inside toe of the reservoir (i.e. 370 ft in from the site boundary on all sides) is approximately 16,600 acres.

2.3.1 Pump Stations

Three pump stations are currently under evaluation for the EAA Reservoir A-1:

- Northeast Pump Station
- Southwest Pump Station
- Pump Station G-370

The Northeast Pump Station would be a new facility located at the northeast corner of the reservoir that would be supplied by the North New River Canal. The Southwest Pump Station would be a new facility located at the point where the Holey Land Distribution Canal turns from flowing east to flowing south to connect with the STA 3/4 Supply Canal. This pump station would be supplied by the flow pumped by G-372 from the Miami Canal into the Holey Land Distribution Canal. Pump station G-370 is supplied by the North New River Canal and may be modified from its current configuration of pumping into the STA 3/4 Supply Canal to a modified configuration of pumping into the EAA Reservoir A-1. Locations of the existing pump stations are shown on Figure 1.

2.3.2 Gate Locations

Gate locations have not been finalized. For the purposes of this evaluation, they will be conceptually located along the southern and eastern embankments of the EAA Reservoir A-1.

The gates along the southern embankment of the reservoir will allow for the release of water into the STA 3/4 Supply Canal to meet the environmental demands of WCA-3A via STA 3/4. The gates along the eastern embankment of the reservoir will allow for the release of water into the North New River Canal to meet agricultural irrigation demands in the EAA. Design of these gates will be performed under a future Work Order.

2.4 Canal Flows

As discussed in the previous section, the source of inflow from canals into the EAA A1 reservoir is from the North New River Canal, Holey Land Distribution Canal, and seepage collection canals.

2.4.1 North New River Canal

The North New River Canal runs parallel to the east side of the EAA Reservoir A-1 boundary. In the WBM, the available flows from the North New River Canal into the reservoir were set equal to the daily average simulated flows at pump station G-370. Pump station G-370 is located at the southeast corner of the EAA Reservoir A-1 and moves water from the North New River Canal to the STA 3/4 Supply Canal. (Kimley-Horn and Associates, 2004) This existing pump station may be modified from its current configuration of pumping into the STA 3/4 Supply Canal to a configuration of pumping into the EAA Reservoir A-1.

According to information obtained at a January 28, 2005 meeting with the District, all flow through G-370 is available as an inflow source into the reservoir. G-370 daily flows representing January 1, 1965 through December 31, 2000 were simulated with the SFWMM and provided by IMC on December 22, 2004.

As illustrated in Figure 9, the maximum flow through pump station G-370 is 2,775 cfs and the average is 214 cfs. The flow is highly variable and consists of 9,423 days of zero flow, or 72 percent of the 36 year simulation period (13,149 days).

2.4.2 Holey Land Distribution Canal

The Holey Land Distribution Canal branches from the Miami Canal and flows east connecting with the EAA Reservoir A-1 along the south half of the west side. In the WBM, the available flows from the Holey Land Distribution Canal into the reservoir were set equal to the simulated daily average flows at pump station G-372. Pump station G-372 is located at the confluence of the Miami Canal and the Holey Land Distribution Canal and moves water from the Miami Canal into the Holey Land Distribution Canal. (Kimley-Horn and Associates, 2004) G-372 simulated flow data were received on March 3, 2005 and are based on IMC staff conversations with the lead modeler of the SFWMM. Based on the latest data received, flows at G-372 were assumed to be:

Flow at G-372 = MIAST3 + 354RG + FLIMPM + WCS4S + EVBLSS + Water Supply from Lake Okeechobee to STA 3/4 via Miami Canal through G-372

Where

MIAST3 is the total outflow to STA 3/4 from Lake Okeechobee (for environmental water supply) and Miami Canal Basin runoff via Miami Canal through pump station G-372.

354RG is the Lake Okeechobee regulatory discharge via structure S354.

FLIMPM is the Import Glades water met by Lake Okeechobee via Miami Canal through structure S354.

WCS4S is the surface water only outflow for environmental water supply purposes from southern surge tank of the EAA reservoir to WCA-3A via STA 3/4.

EVBLSS is the subsurface water outflow down to 1.5 ft below land surface for environmental water supply purposes from southern surge tank in the EAA reservoir.

Water Supply from Lake Okeechobee to STA 3/4 via Miami Canal through G-372 is the flow assumed to equal:

Water Supply from Lake Okeechobee = 354WS – FLIMPM – WLC354 – LKTSEM – WSHOLY

Where

354WS is the Glades environmental releases plus Lower East Coast (LEC) water supply met by Lake Okeechobee via S354.

FLIMPM is described above.

WLC354 is the water supply discharges to LEC from Lake Okeechobee via structure S354.

LKTSEM is the water supply from Lake Okeechobee to meet supplemental Big Cypress Seminole Indian Reservation (BCR) demands.

WSHOLY is the environmental water supply releases from Lake Okeechobee to the Holey Land.

However, *Water Supply from Lake Okeechobee* is only applicable if lower than the environmental water supply from Lake Okeechobee to STA ¾ (WSSTA3). The values under *WCS4S* and *EVBLSS* are for a reservoir with a storage capacity of 360,000 acre-ft and were adjusted for a reservoir with a storage capacity similar to the EAA Reservoir A-1 of 199,000 acre-ft. The adjusted values did not vary with additional changes in depth.

As illustrated in Figure 10, the maximum flow through pump station G-372 is 3,700 cfs and the average is 867 cfs. The flow is highly variable and consists of 6,400 days of zero flow or 49 percent of the 36 year simulation period (13,149 days).

This flow is significantly greater than the flow determined from data presented by the IMC at the January 28, 2005 meeting with the District, where the available flow at G-372 was assumed to be the flow at structure S8 minus the flow at L4. S8 flow data had been submitted by IMC on December 22, 2004. L4 data were provided by IMC on February 3, 2005, together with Figure 11, which illustrates the routed flow from storage areas north of WCA-3A to WCA-3A with rain driven operations.

The maximum flow through pump station G-372 based on the assumption of January 28 was 2,281 cfs and the average flow was 299 cfs. The flow was also highly variable, consisting of 6,865 days of zero flow or 52 percent of the 36 year simulation period (13,149 days).

It is important to note that the most recent G-372 data provide an additional amount of flow available as an inflow source into the reservoir. The maximum flow of 3,700 cfs, and the average flow of 867 cfs, are, respectively, 1400 cfs and 570 cfs greater than the

maximum and average flows of the January 28 assumption. This additional flow results in the reservoir meeting a greater portion of the simulated irrigation and environmental demands without dropping below the reservoir's minimum water surface elevation (WSE). The reservoir's minimum WSE was assumed to be 9.1 ft or 0.5 ft of depth, below which environmental and irrigation demands could not be supplied.

2.4.3 Agricultural Flows

As previously discussed, the Northeast Pump Station may be located at the northeast corner of the reservoir, along the North New River Canal. If this pump station is evaluated for implementation, then all inflows and outflows along the North New River Canal between the locations of the Northeast Pump Station and G-370 must be accounted for in the modeling. A review of available information provided by the District showed that seven agricultural structures are located between the proposed Northeast Pump Station and G-370. These structures can either discharge water into the North New River Canal from the associated agricultural areas, or withdraw water from the North New River Canal to be used for irrigation, based upon farming requirements. To accurately account for the flow in the North New River Canal at the Northeast Pump Station when provided with the flow through structure G-370, the discharges and withdrawals between these locations must be determined.

Various District personnel were contacted to further identify the structures and to obtain the actual and permitted discharge and withdrawal information. Black & Veatch contacted personnel in the DBHYDRO Department, Water Supply Department, and Everglades Regulation Division for information. The information obtained from the District pertaining to farm structures within the North New River Canal along the reservoir alignment is listed in Table 1.

The discharge data were evaluated for the POR of January 1, 1993 through December 31, 2000 for each farm structure. The cumulative flow data from the POR were compared with the corresponding flow through structure G-370, as illustrated in Figure 12. The maximum agricultural discharge from the seven farm structures was 1,217 cfs for the available POR. As a comparison, the maximum discharge through structure G-370 was 2,775 cfs during the same time frame. The average agricultural discharge from the seven farm structures for the POR was 90 cfs. The average flow through structure G-370 for the same POR was 203 cfs.

Water withdrawals from the North New River Canal between the Northeast Pump Station and G-370 must also be considered when analyzing the flow available at the Northeast Pump Station. Withdrawal information was based upon the permitted annual allocation for the five Water Use Permits (WUP) located along the North New River Canal between the Northeast Pump Station and structure G-370. Actual flow information is not required by the WUP. Table 2 summarizes the water withdrawal permit information. The total average permitted withdrawal from these five farms is 97 cfs.

The average annual withdrawal of 97 cfs from the North New River Canal is similar to the average annual discharge of 90 cfs from the five farms. Therefore, it appears reasonable to assume the flow through structure G-370 represents the flow at the Northeast Pump Station.

2.5 Diversion and Release Rates

Diversions into the EAA Reservoir A-1 will be from 2 sources, the North New River Canal and the Holey Land Distribution Canal. The intention for inflow into the reservoir from these sources is to capture all the flow available in the canals and redirect them to the reservoir, where they will be stored and released to meet the simulated environmental and irrigation demands in the EAA.

Release rates from the reservoir will be based on the amount of flow required to meet the environmental and irrigation demands in the area when sufficient storage is available. During periods of limited storage, the demands may not be fully met by the reservoir and releases will be a function on the amount of water available up to the established minimum water surface elevation in the reservoir. Flow releases required to meet the environmental demands will discharge via the STA 3/4 Supply Canal to STA 3/4 and subsequently to WCA-3A. Flow releases to meet the irrigation demands will discharge via the North New River Canal.

The maximum environmental demand to be met by the reservoir is 4,060 cfs, the average demand is 627 cfs, and there is no environmental demand on 9,739 days over the POR (74 percent). The maximum irrigation demand to be met by the reservoir is 4,473 cfs, the average demand is 424 cfs, and there is no irrigation demand on 5,761 days over the POR (44 percent). However, due to the scale of the figures the number of days with no demands are not apparent.

3. MODEL RELIABILITY

Conventional methods for performing calibration and verification of the WBM are not available since data for the reservoir and flow conditions do not exist. The model is based on the best data available and will be refined as new information is collected under future Work Orders. The work conducted to ensure the reliability of the results of the WBM was focused on the input data and calculations performed by the model.

Mean daily precipitation data were obtained from the SFWMM for the 10 cells that encompass the EAA A1 reservoir footprint. Inflow data was based on actual precipitation values for the POR, from January 1, 1965 to December 31, 2000. The average value of all 10 cells for each day in the POR was used as input data for the WBM.

Inflows and outflows used in the WBM were provided by the District and the USACE Interagency Modeling Center, based on simulations using the SFWMM. The SFWMM provides simulated flows from both the North New River Canal, which runs parallel to the east side of the EAA A1 reservoir boundary, and the Miami Canal, located west of the reservoir boundary. Simulated flows from the North New River Canal and Miami Canal were based on future (year 2050) operating schedules for Lake Okeechobee, future land use projections, as well as the future release schedules for the STAs.

Evapotranspiration (ET) data were obtained from the SFWMM for the 10 cells that encompass the EAA Reservoir A-1 footprint. The ET data used in the SFWMM were compared to historical direct evaporation data downloaded from DBHYDRO for the area in the vicinity of the EAA Reservoir A-1. A comparison of the ET data, used in the SFWMM, to actual evaporation data revealed little difference between the two values indicating that the data were reliable.

Seepage at the dam was estimated to be 317 cfs, based on information from the *Levee Optimization Report* (Jacobs/Montgomery Joint Venture, 2004). As part of a future Work Order, the WBM will be updated with the seepage results from the test cells program.

The site boundary was determined from aerial photography based on the land acquired by the District for the proposed EAA Reservoir A-1 site. Until the test cell results are available, some assumptions are necessary to develop a preliminary stage/area/storage relationship for input into the WBM. These included assumptions for the setback from the site boundary, side slopes, height and top width of the embankment. These assumptions result in a total setback from the site boundary to the inside toe of the reservoir embankment of approximately 370 ft. The entire site boundary is approximately 17,600 acres, with the southern boundary being approximately 6.2 miles in length and the shortest distance from the north to the south boundary is approximately 6.4 miles. The area defined by the inside toe of the reservoir is approximately 16,600 acres.

The water balance model has been checked by verifying that the equations perform the proper calculations and reference the correct information in the model. Because the model simulates future conditions, it is not possible to compare results to historic values. Therefore, focus was on independent verification of the values used in the model, the equations used, and the calculations performed.

4. INITIAL ALTERNATIVE EVALUATION

4.1 Water Balance Model

The WBM of the EAA Reservoir A-1 was developed to analyze and optimize the storage capacity and operations of the reservoir, while evaluating the impacts on flows in EAA. To make the model more user-friendly, a graphical user interface (GUI) was created to allow the input of reservoir characteristics and display results. The GUI comprises four parts: *Review Notes, Input, Output, and Output Graphs*. The WBM GUI is shown on Figure 14 and the description of each part follows.

The *Review Notes* provide specific information on the input data used in the model including canal flows, precipitation, evaporation, reservoir characteristics, seepage, and demands.

The *Input* is divided into *Reservoir, Seepage, Flow Captured, Available Flows, Demands,* and *Target Depth* information.

Reservoir information includes:

- Starting conditions of the reservoir. The model has the capability to evaluate a reservoir that is “Full” or “Empty” at the commencement of a run
- Target Water Depth in the reservoir (ft)
- Reservoir Bottom Elevation (ft)
    - The reservoir bottom elevation is set at 8.6 ft
- Bank Maximum Height (ft)

  - The bank maximum height is set at 25 ft

Seepage (cfs):

- Seepage at the Dam and Collected Seepage information was obtained from the Levee Optimization Report (Jacobs/Montgomery Joint Venture, 2004)
  - Seepage at the Dam is 317 cfs
  - Collected seepage is 175 cfs
- Seepage information will be updated with Test Cells results once available

Flow Captured (%):

- Allows the user to enter the percentage of flow captured for inflow into the reservoir from the North New River Canal, Holey Land Distribution Canal, and seepage canals

Available Flows (cfs):

- Simulated available flows for inflow into the reservoir include flows in the North New River Canal and Holey Land Distribution Canal
- The model allows the user to select between the two sources of flow, as well as the pumping rate into the reservoir

Demands (cfs):

- Demands information is divided into Irrigation and Environmental demands
- The model allows the user to vary demand information as a percentage of the total demand

Target Depth (ft)

- A specific Target Depth may be selected to evaluate the number of days the reservoir is over the specified value

Output information provided by the WBM includes:

- Reservoir Minimum WSE (ft)
- Reservoir Target WSE (ft)
- Reservoir Target Volume (acre-ft)
- The Target Volume is the volume available at the Target WSE
- Number of Days Demands are Not Met
  - Demands are not met when the reservoir WSE is below the minimum WSE
  - The Days Demands are Not Met are also provided as a percentage from the POR
- Maximum Number of Consecutive Days Demands are Not Met
  - The model also provides this information as the Number of Months and specifies the Year Occurring

- Available Flows in the North New River Canal (cfs)
  - Provides maximum and average available flows in the North New River Canal
- Available Flows in the Holey Land Distribution Canal (cfs)
  - Provides maximum and average available flows in the Holey Land Distribution Canal
- Target WSE (ft)
  - This is the resulting WSE based on the Target Depth entered in the Input section
- Number of Days Reservoir is over the Target Depth or WSE
  - This information is also provided as a percentage from the POR

The Output Graphs provides graphic results of the WBM *Output* and includes:

- Storage vs. Time
  - A preview of this graph is provided in the main WBM screen.
- Stage vs. Time
  - A preview of this graph is provided in the main WBM screen
- North New River Canal Flows vs. Time
- Holey Land Distribution Canal Flows vs. Time
- Irrigation Demands vs. Time
- Environmental Demands vs. Time

4.2 Evaluation of Alternatives

Four main alternatives were evaluated in the WBM. The alternatives included:

- Alternative 1: A reservoir with a depth of 12 ft, starting empty, capturing all available flows in the canals, and meeting 100 percent of the simulated irrigation and environmental demands
- Alternative 2: A reservoir with a depth of 12 ft, starting full, capturing all available flows in the canals, and meeting 100 percent of the simulated irrigation and environmental demands
- Alternative 3: A reservoir with a depth of 15 ft, starting empty, capturing all available flows in the canals, and meeting 100 percent of the simulated irrigation and environmental demands
- Alternative 4: A reservoir with a depth of 15 ft, starting full, capturing all available flows in the canals, and meeting 100 percent of the simulated irrigation and environmental demands

Two main criteria were considered when evaluating the reservoir that would provide the most effective use of storage to meet the simulated environmental and irrigation demands. These included the number of days demands are not met and the maximum number of consecutive days demands are not met. The demands not met are accounted in the model as 100 percent of the demands. To meet most of the demands, the available storage in the reservoir should be discharged each year, based on the demands requirements. As a result, maximizing the use of the reservoir's storage, while controlling the number of days the reservoir is empty would provide the most effective use of storage. Table 3 lists the WBM results for each alternative and Figures 15 through 26 illustrate the WBM input and output screens with the respective Storage vs. Time and Stage vs. Time graphs for each case.

Table 3 shows that starting with an empty reservoir results in a greater number of days demands are not met (483 for a 12-ft deep reservoir and 395 for a 15-ft deep reservoir) and a greater number of consecutive days demands are not met (79). This is because the reservoirs are supplying demands from the beginning of the POR. A reservoir that starts empty does not supply any of the demands until it exceeds the minimum water surface elevation. Based on the available flows, a 12-ft deep reservoir reaches its target volume in about 9 months and a 15-ft deep reservoir reaches its target volume in approximately 9.5 months. It is important to note that the maximum number of consecutive days demands are not met for the reservoirs that start empty occurs early in the POR, when the reservoirs are filling up.

The reservoirs that start full, have a lower number of days demands are not met (348 for a 12-ft deep reservoir and 241 for a 15-ft deep reservoir) and a lower number of maximum consecutive days demands are not met (68 and 66, respectively). The maximum number of consecutive days demands are not met occurs in 1990, towards the end of the POR. Both of these projections are based on the conditions during the POR. The actual conditions after reservoir EAA A-1 is constructed will determine the demands that are met.

The percentage of the simulated irrigation and environmental demands to be met by the reservoir may be adjusted to limit the number of days and maximum number of consecutive days demands are not met to a desired value. This value will be evaluated in a future Work Order as future reservoir management decisions are made.

5. CONCLUSIONS

This memorandum summarizes the work conducted to develop the WBM for the EAA Reservoir A-1. Included is a discussion of the Model Configuration and Data Sources, Model Reliability, and Initial Alternative Evaluation to demonstrate the suitability of the model for the analysis of alternatives for the design of the reservoir.

The WBM was developed to analyze the storage capacity and operations of the EAA Reservoir A-1 on a daily time step. The model was used to optimize the storage capacity of the reservoir, while evaluating the impacts on flows in the EAA.

The basic water balance equation is: $\Delta S = P + I - O - E - S$,
Where:

> *DS* is the change in storage in the reservoir on a daily basis based on inflows and outflows.
>
> *P* is the Precipitation inflow into the reservoir.

I is the Inflow into the reservoir from the North New River Canal, Holey Land Distribution Canal, and seepage canals.

O is the Outflow from the reservoir to meet irrigation and environmental demands, and excess volume flows during periods of maximum storage capacity.

E is the Evaporation outflow from the reservoir.

S is the Seepage outflow from the reservoir.

The WBM is maintained in Microsoft Excel and incorporates formulas and Visual Basic programs to calculate changes in storage and stage over the POR, which extends for 36 years, from January 1, 1965 to December 31, 2000. The reservoir site boundary was determined from aerial photography based on the land acquired by the District for the proposed site. The entire site boundary is approximately 17,600 acres and the area defined by the inside toe of the reservoir is about 16,600 acres. At a depth of 12 ft, the reservoir provides a storage capacity of 199,000 acre-ft.

Available flows in the North New River Canal were set equal to the daily average simulated flows at pump station G-370. Holey Land Distribution Canal flows were set equal to the simulated daily average flows at pump station G-372. The intention for inflow into the reservoir from these sources is to capture all the flow available in the canals and redirect them to the reservoir.

Agricultural flows were evaluated to account for all the flows into and out of the North New River Canal. Agricultural flows include withdrawal and discharges to and from the North New River Canal from farms along the reservoir boundary. This information is important when evaluating canal flows at a specific location along the North New River Canal.

Four initial alternatives were evaluated in the WBM for this technical memorandum. The alternatives included:

- Alternative 1: A reservoir with a depth of 12 ft, starting empty, capturing all available flows in the canals, and meeting 100 percent of the simulated irrigation and environmental demands
- Alternative 2: A reservoir with a depth of 12 ft, starting full, capturing all available flows in the canals, and meeting 100 percent of the simulated irrigation and environmental demands
- Alternative 3: A reservoir with a depth of 15 ft, starting empty, capturing all available flows in the canals, and meeting 100 percent of the simulated irrigation and environmental demands
- Alternative 4: A reservoir with a depth of 15 ft, starting full, capturing all available flows in the canals, and meeting 100 percent of the simulated irrigation and environmental demands

The main criteria considered to provide the most effective use of storage and maximize the environmental and irrigation demands met include the number of days demands are not met and the maximum number of consecutive days demands are not met. To meet most of the demands, the available storage in the reservoir should be discharged each year, based on the demands requirements. As a result, maximizing the use of the reservoir's storage, while controlling the number of days the reservoir is empty would provide the most effective use of storage.

Modeling results show that starting with an empty reservoir results in a greater number of days demands are not met and a greater number of consecutive days demands are not met. The maximum number of consecutive days demands are not met for a simulation that assumes an empty reservoir starting condition occurs early in the POR, when the reservoir is filling up. The maximum number of consecutive days demands are not met for a simulation that assumes a full reservoir starting condition occurs in 1990, towards the end of the POR.

The reservoirs that start full have a lower number of days demands are not met and a lower number of maximum consecutive days demands are not met. The percentage of the simulated irrigation and environmental demands to be met by the reservoir may be adjusted to limit the number of days and maximum number of consecutive days demands are not met to a desired value. This value will be evaluated in a future Work Order as future reservoir management decisions are made.

6. REFERENCES

Brion, L. M., May 1999, A Primer to the South Florida Water Management Model (version 3.5), South Florida Water Management District, HSM Department, Water Supply Division.

Brion, L.M. and A. Ali, April 15, 2002, ECP Base Simulation and 2050 with Project Simulation Using the South Florida Water Management Model, South Florida Water Management District MEMORANDUM.

Hornung, L., Brion, L.M., and A. Prymas, undated, EAA Storage Reservoir Project, Identification of the Tentatively Selected Plan.

Jacobs/Montgomery Joint Venture, May 20, 2004, Report for Conceptual Levee Height Alternatives, Central and Southern Florida Project, Comprehensive Everglades Restoration Plan, Everglades Agricultural Area Storage Reservoir A-1 Levee Optimization.

Kimley-Horn and Associates, Inc., January 2004, Comprehensive Everglades Restoration Plan, Central and Southern Florida Project, Everglades Agricultural Area Storage Reservoirs – Phase I, B.2 Hydraulics, B.2.3 Hydrologic Model Calibration and Verification.

Kimley-Horn and Associates, Inc., June 2004, Comprehensive Everglades Restoration Plan, Central and Southern Florida Project, Everglades Agricultural Area Storage Reservoirs – Phase I, H, Existing Conditions, H.6 Water Management.

TABLES

Table 1 Farm Structure Data

Structure Id.	Sub-Basin Id.	Everglades Permit No.	Period of Record
NR12.5TE	50-062-02	50-00062-E	10/13/93 – 05/14/04
NR11.4TE	50-062-09	50-00047-E	10/13/93 – 10/18/04
NR10.3TE	50-062-05	50-00047-E	10/13/93 – 10/18/04
NR09-0TE	50-062-05	50-00047-E	10/13/93 – 10/18/04
NR07.8TE	50-009-02	50-00009-E	01/01/93 – 12/07/04
NR06.6TE	50-009-02	50-00009-E	01/01/93 – 12/07/04
NR05-4TE	50-006-01	50-00066-E	10/13/93 – 05/19/03

Table 2 Water Withdrawal Permit Information

WUP Number	Sub-Basin Id.	Name	Average Allocation (cfs)
50-00295-W	50-062-02	Okeelanta Corporation	23.4
50-00643-W	50-062-09	Farm 50 New Hope	39.5
50-00164-W	50-062-05	Farm	11.4
50-00047-W	50-009-02	Carroll Farm	6.9
50-00313-W	50-006-01	Woerner South	15.7

Table 3 Results of Alternatives Evaluation

Alternative	Reservoi r Depth, ft	Reservoir Starting Conditions	Reservoir Target Volume, acre-ft	No. of Days Demands are not Met	Max. No. of Consecutive Days Demands are Not Met
Alternative 1	12	Empty	199,169	483	79
Alternative 2	12	Full	199,169	348	68
Alternative 3	15	Empty	249,151	395	79
Alternative 4	15	Full	249,151	241	66

Task 2.10 Revised Water Balance Model Technical Memorandum 2

FIGURES

Figure 1 EAA Basin Project Area

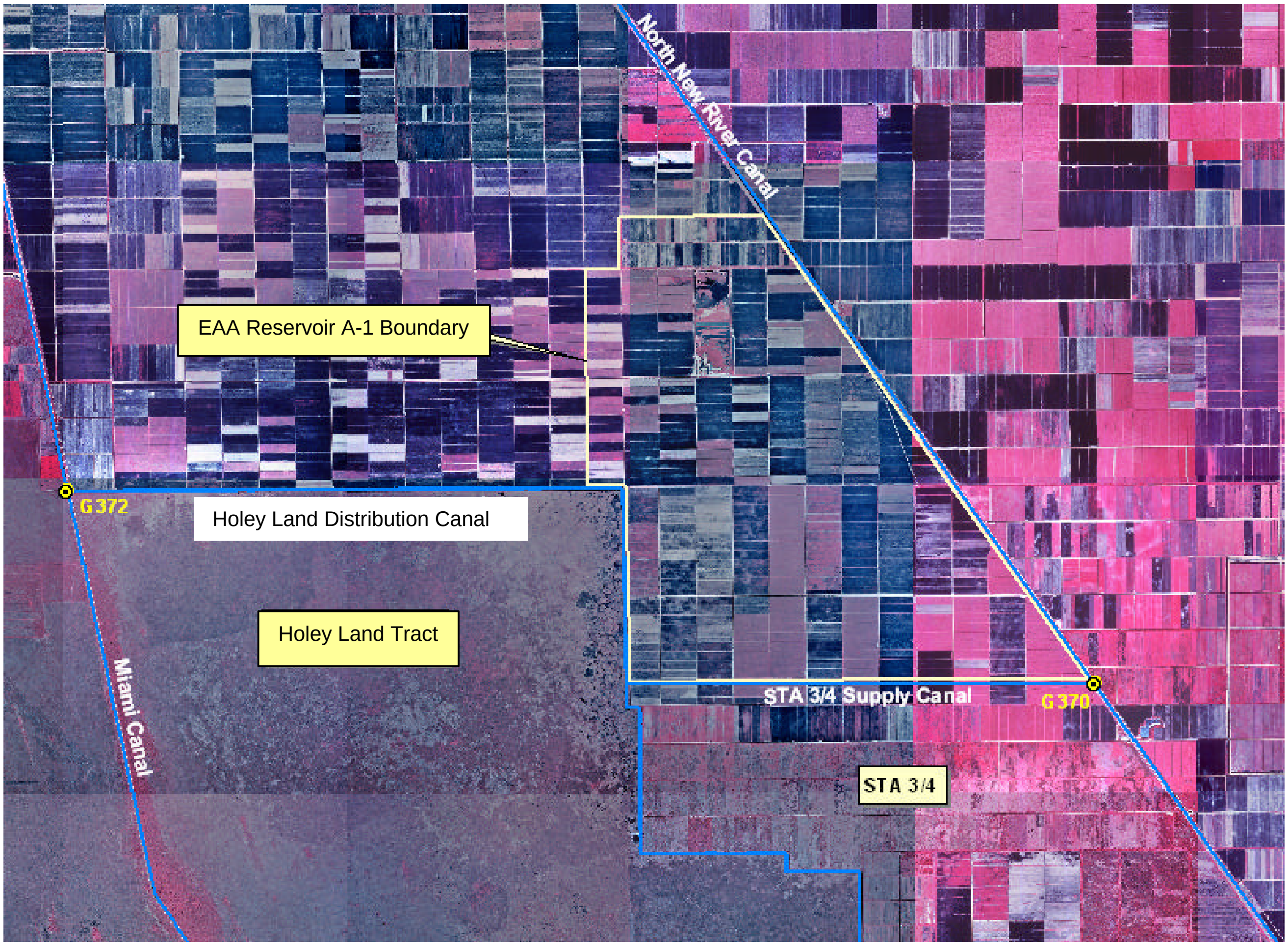


Figure 2 SFWMM 360,000 Acre-ft reservoir

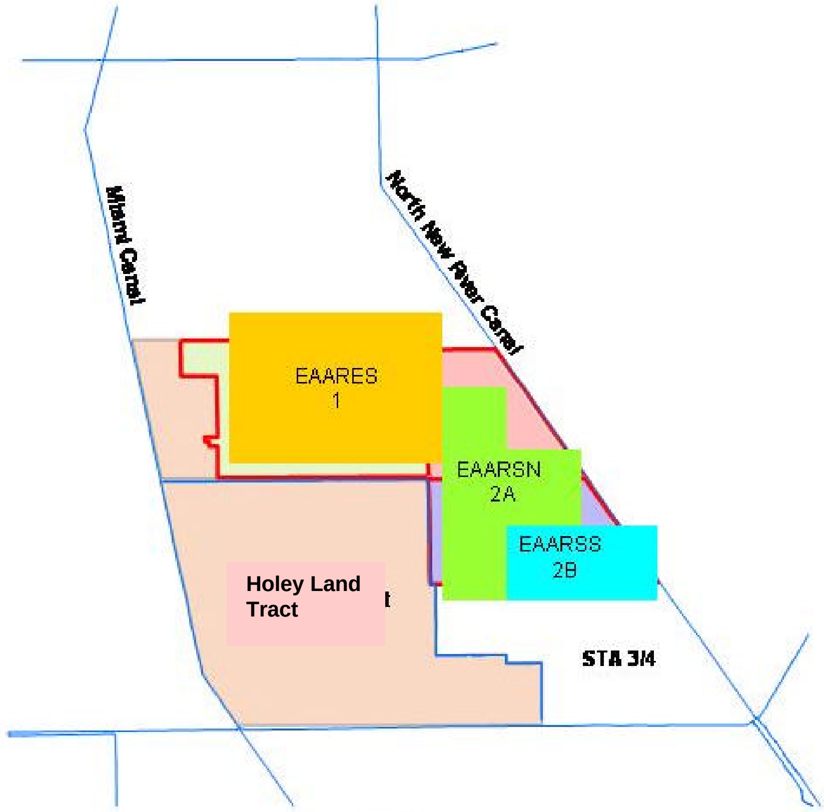


Figure 3 EAA Reservoir A-1 Footprint

Figure 4 Daily Average Precipitation for the EAA Reservoir A-1

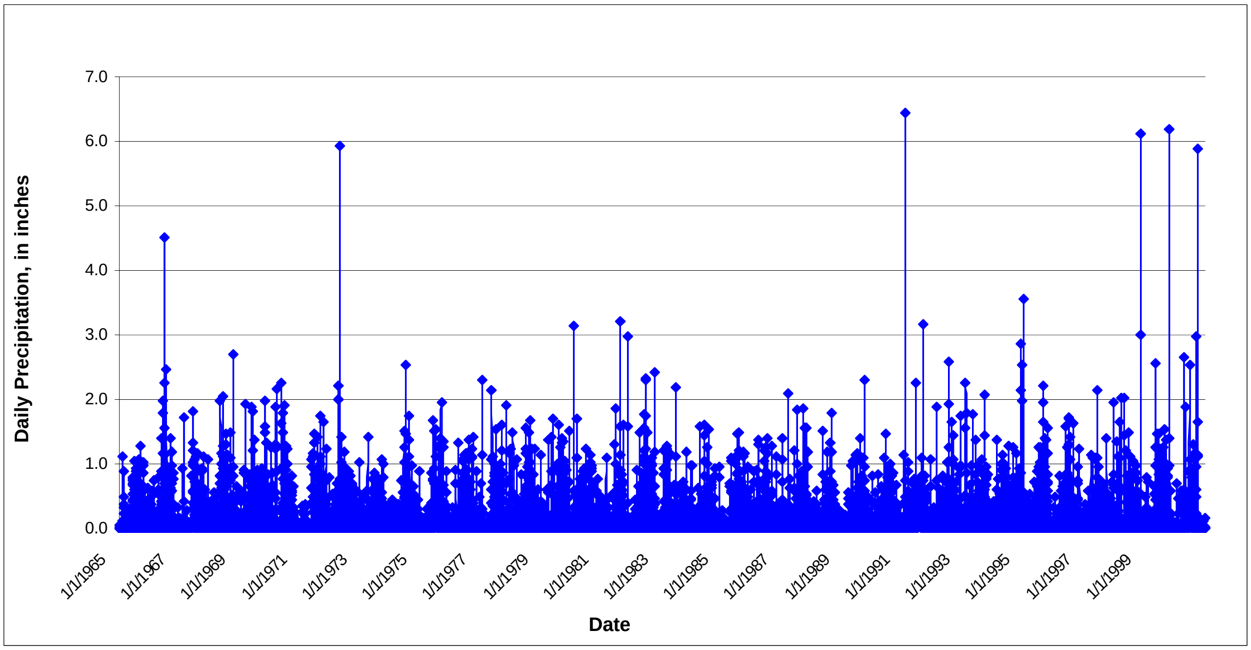


Figure 5 Daily Average Evaporation for the EAA Reservoir A-1

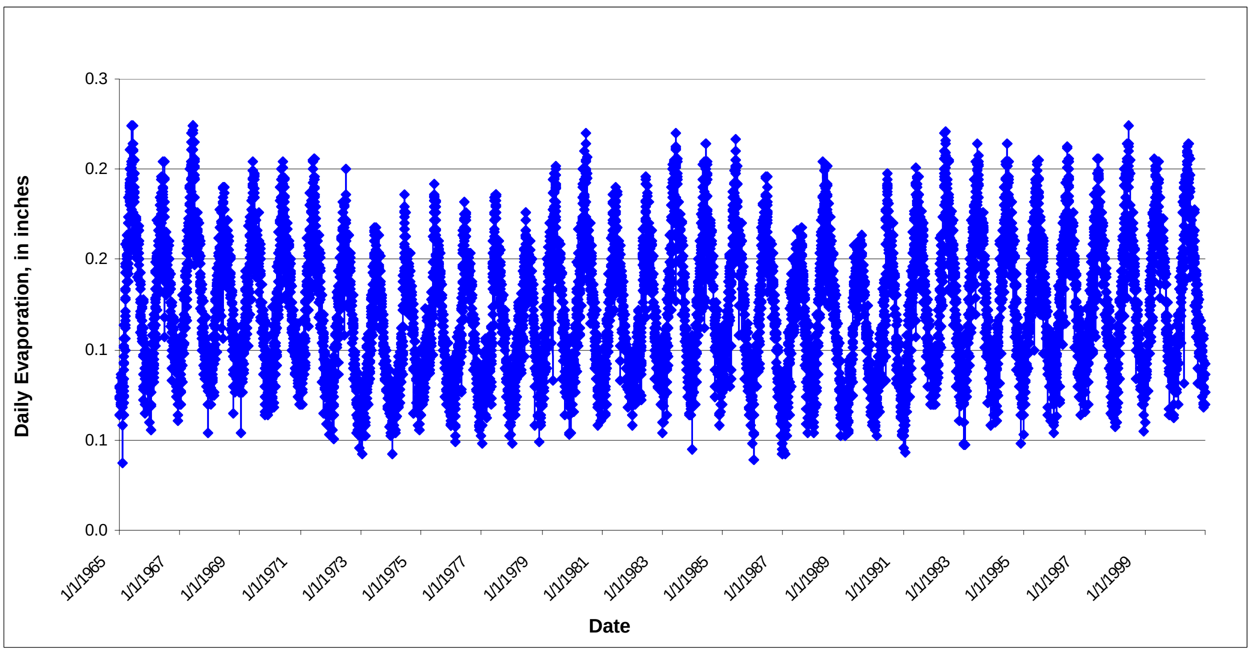


Figure 6 Irrigation Demands from the SFWMM Simulation

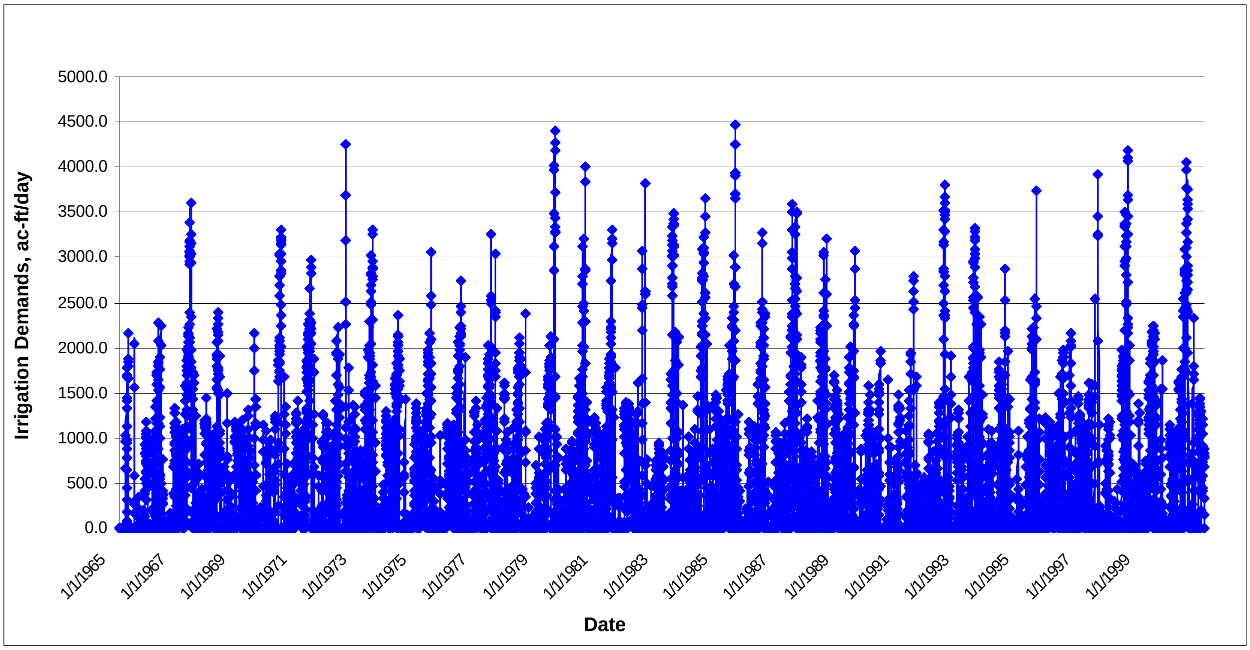


Figure 7 Environmental Demands from the SFWMM Simulation

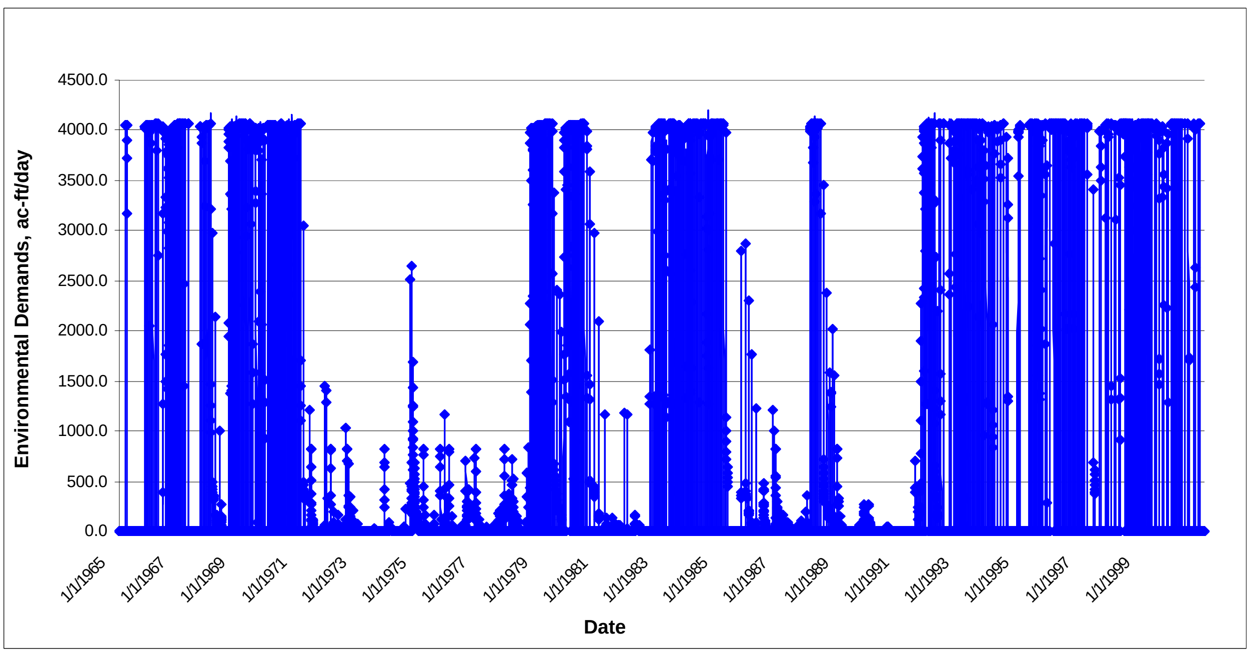
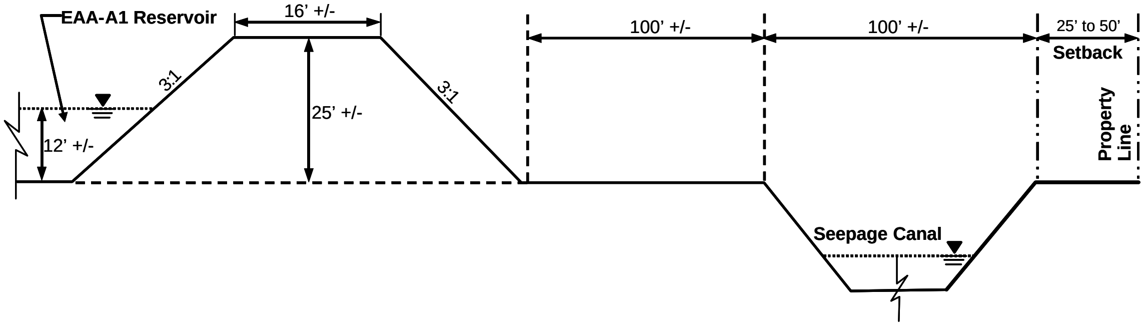


Figure 8 Typical Embankment and Seepage Canal Cross-Section



(Setback is estimated to be 25 ft on the east side and 50 ft on the north side of the reservoir. Setback is estimated to be between 25 ft and 50 ft on the west and south sides of the reservoir.)

Figure 9 Daily Average Flow from the North New River Canal at Structure G-370, as simulated for the POR

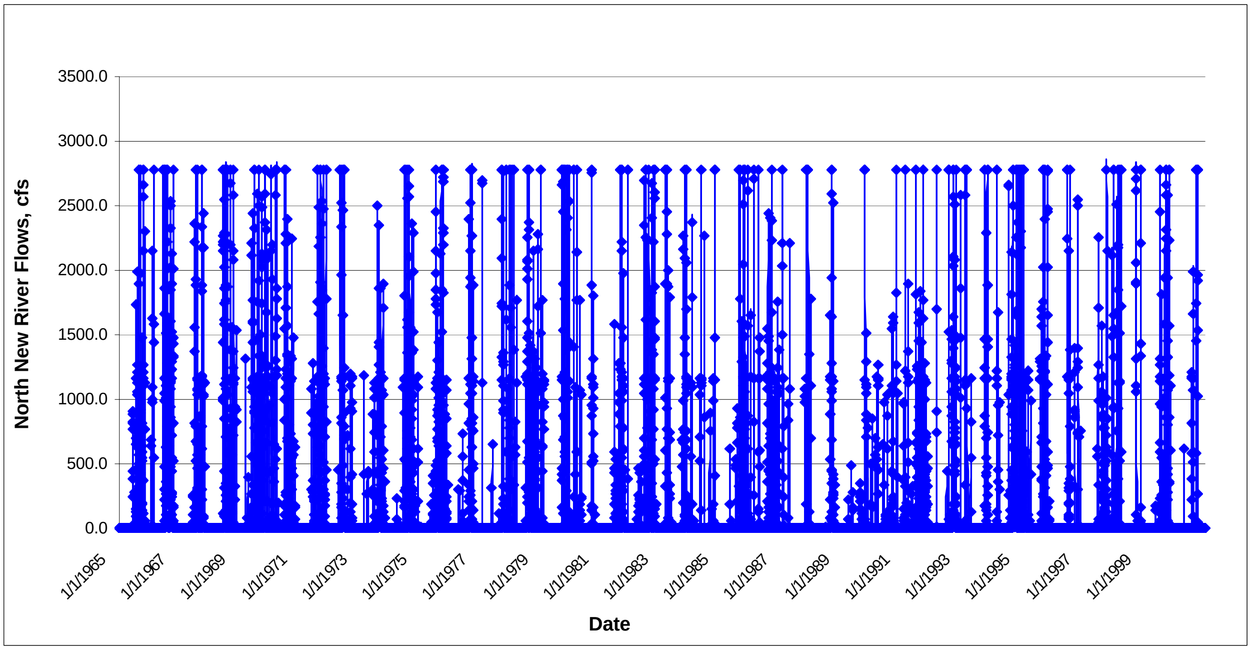


Figure 10 Daily Average Flow from the Holey Land Distribution Canal at Structure G-372, as simulated for the POR

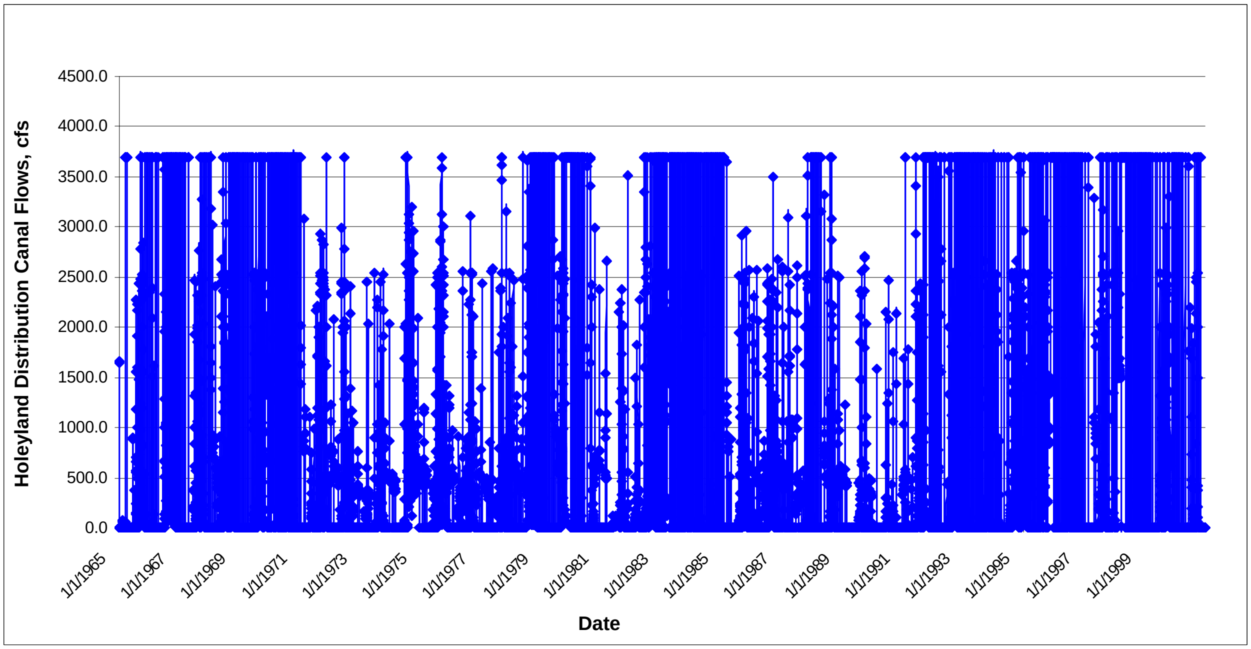


Figure 11 Routing of Outflow from Storage Areas North of WCA-3A to WCA-3A with Rain Driven Operations (source: District)

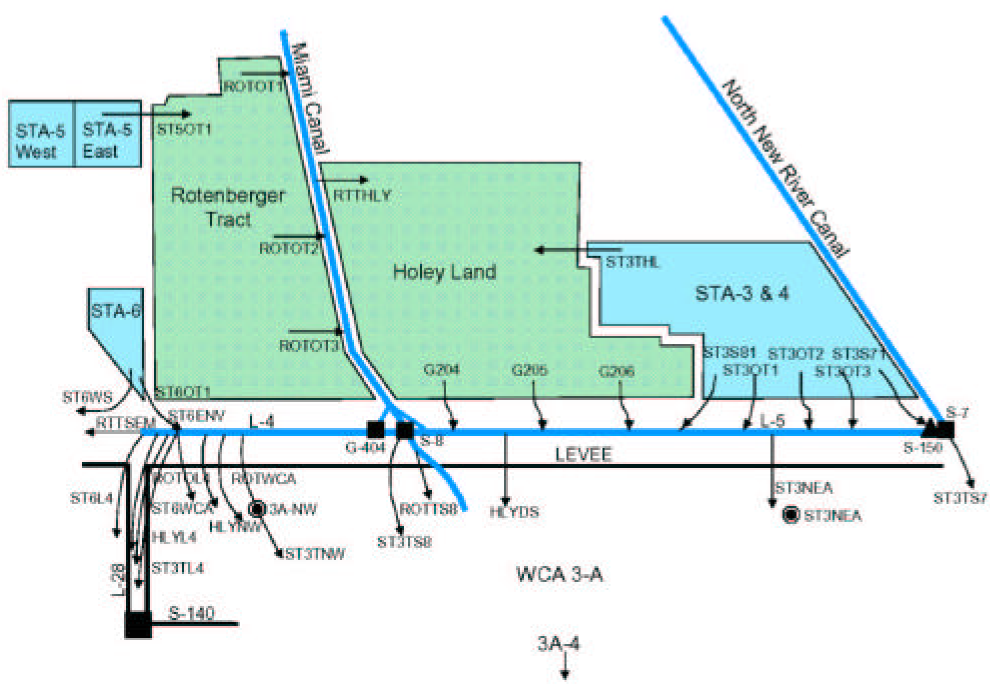


Figure 12 Agricultural and Pump Station G-370 Flows over POR

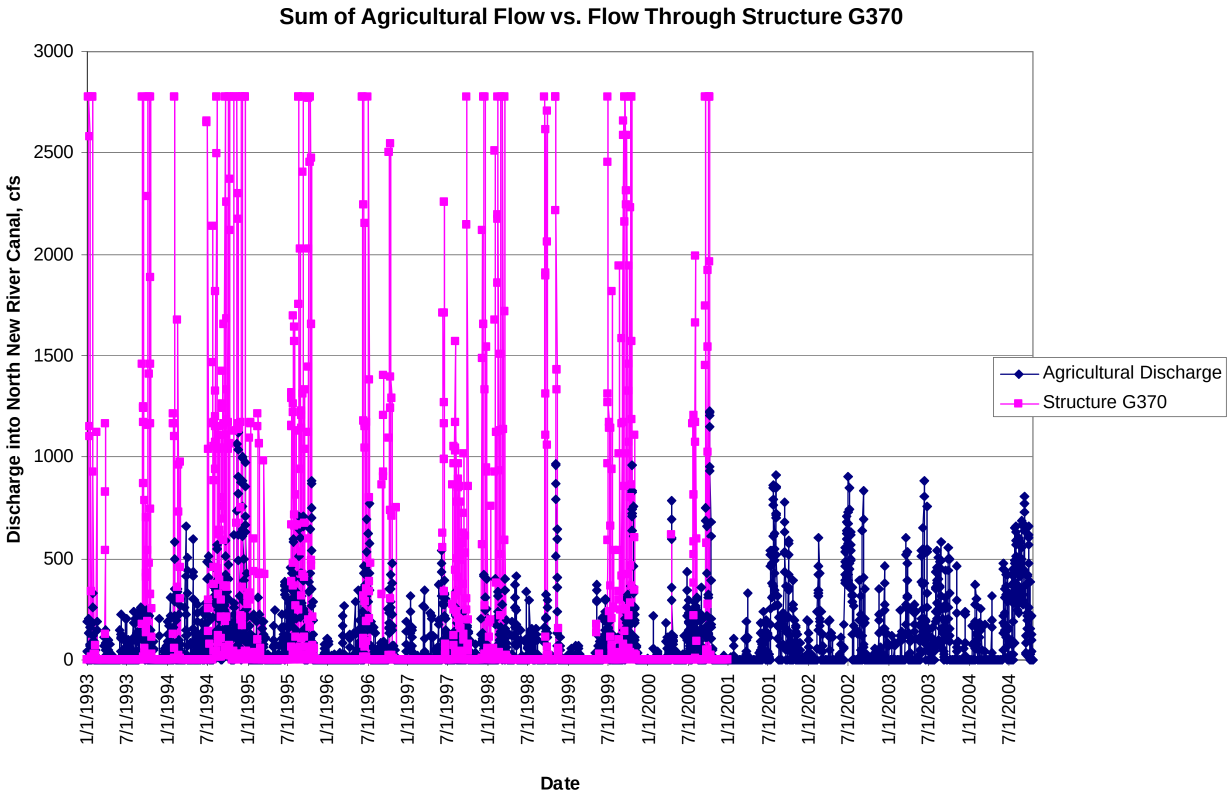


Figure 13 Monthly Averages of Agricultural and Pump Station G-370 Discharges

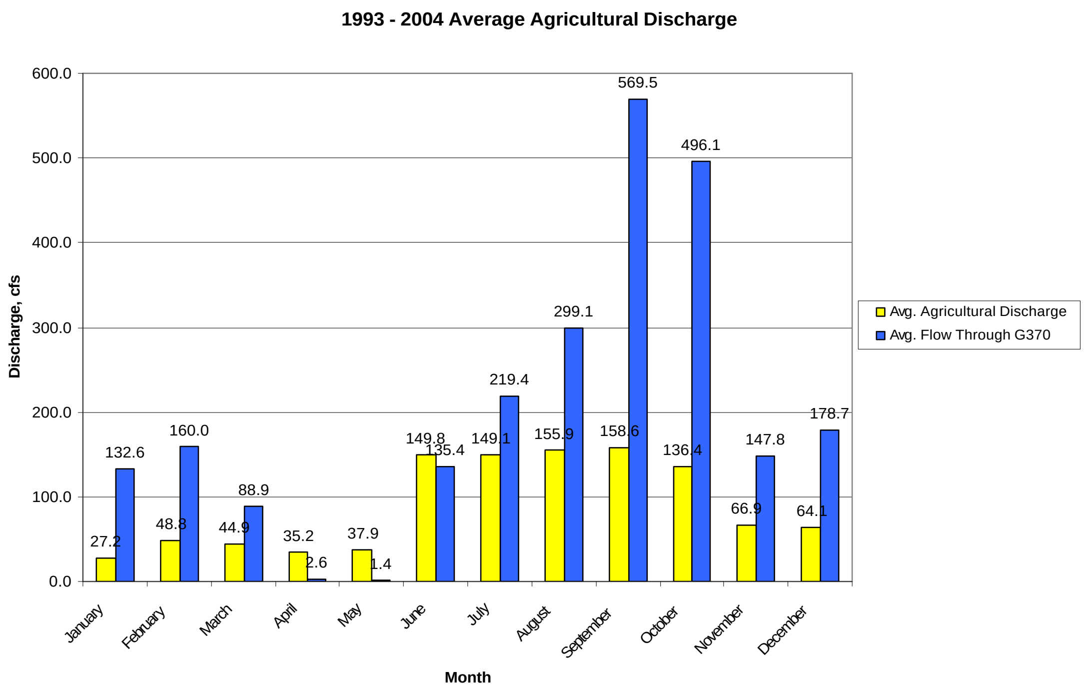


Figure 14 Water Balance Model Graphic User Interphase

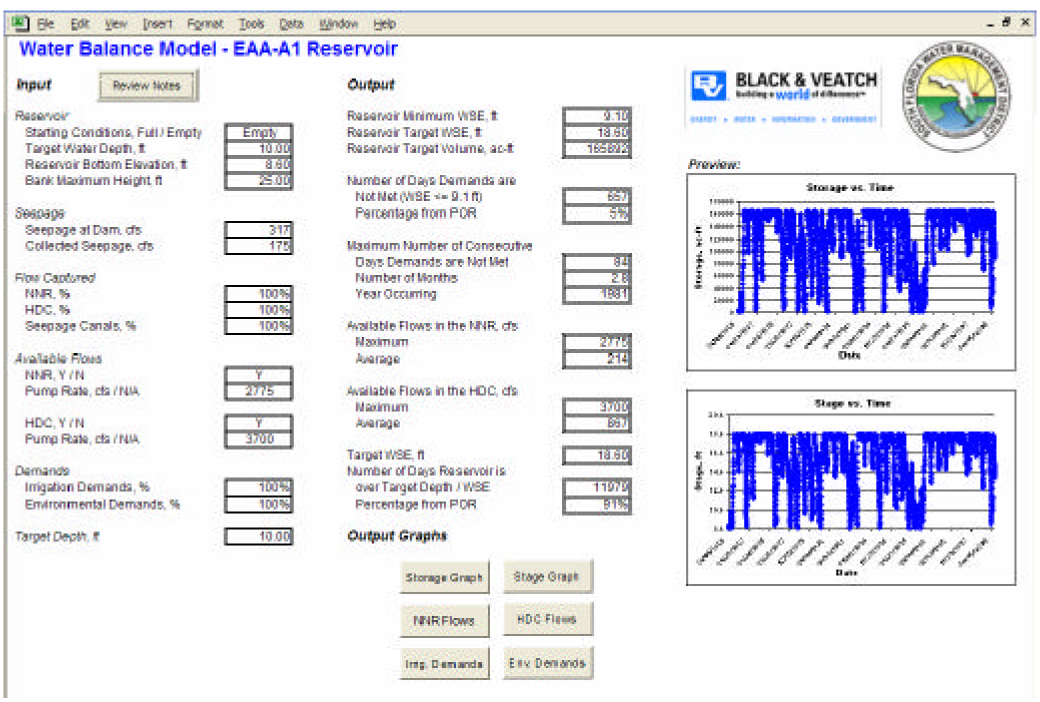


Figure 15 WBM Input and Output Screen for Alternative 1

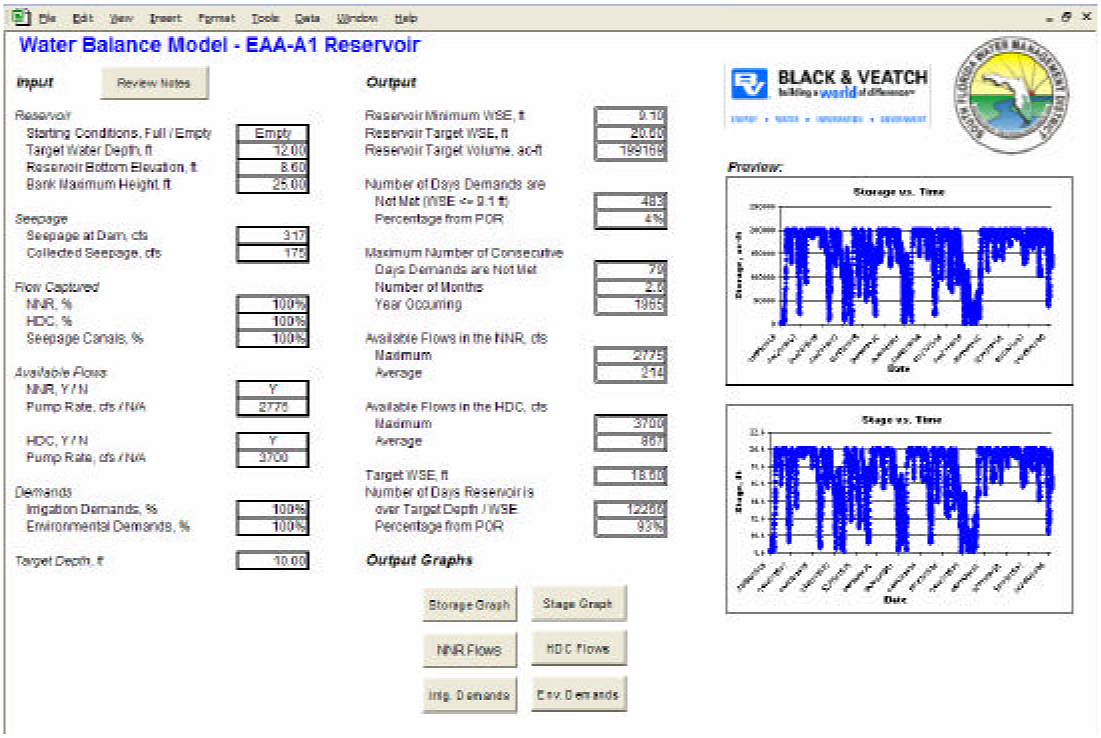


Figure 16 Storage versus Time from WBM Alternative 1

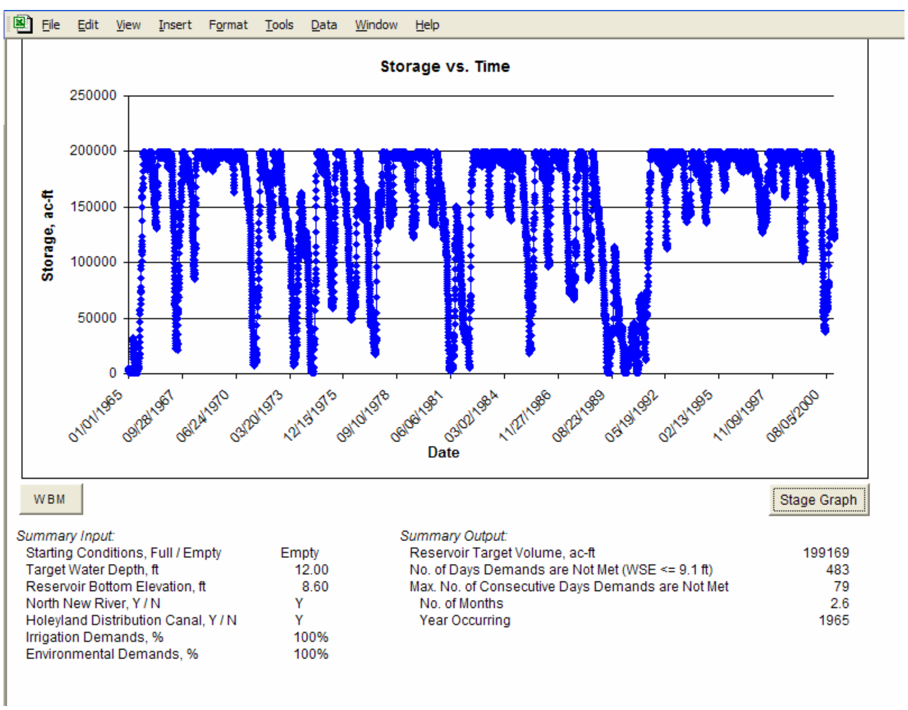


Figure 17 Stage versus Time from WBM Alternative 1

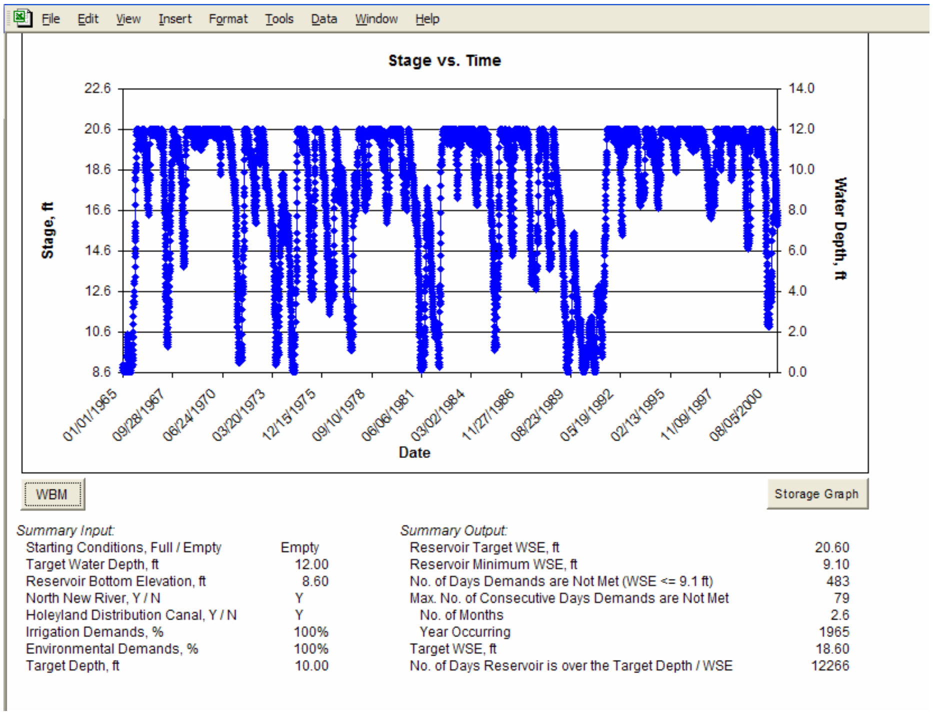


Figure 18 WBM Input and Output Screen for Alternative 2

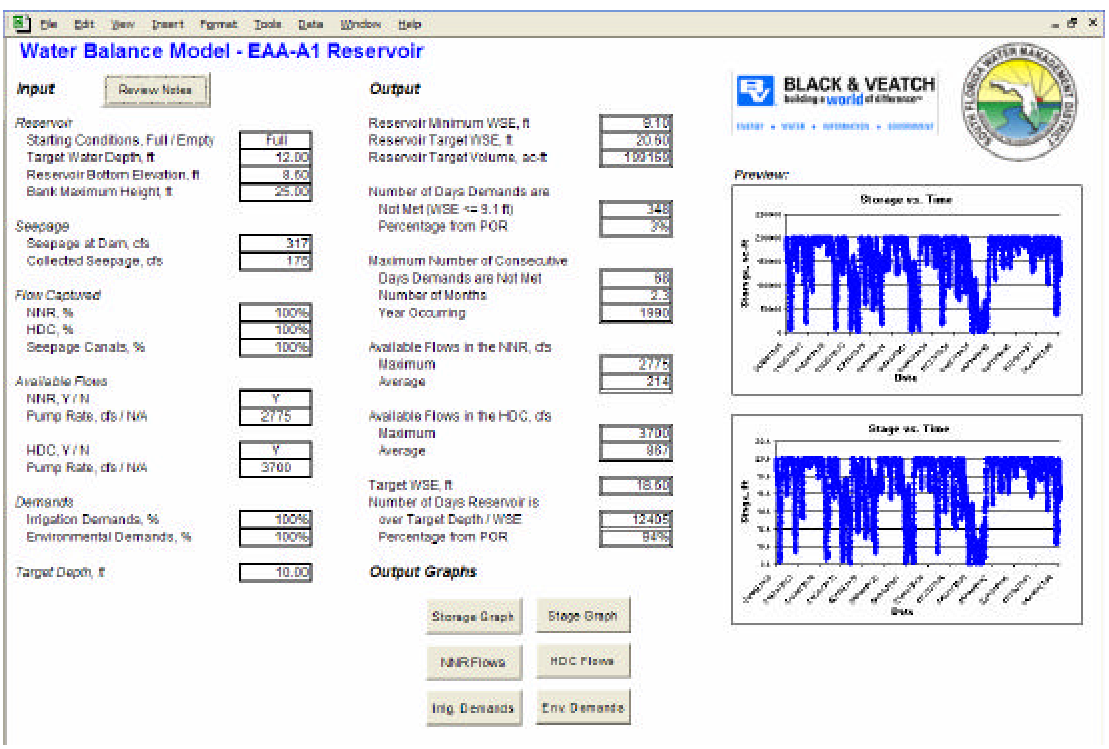
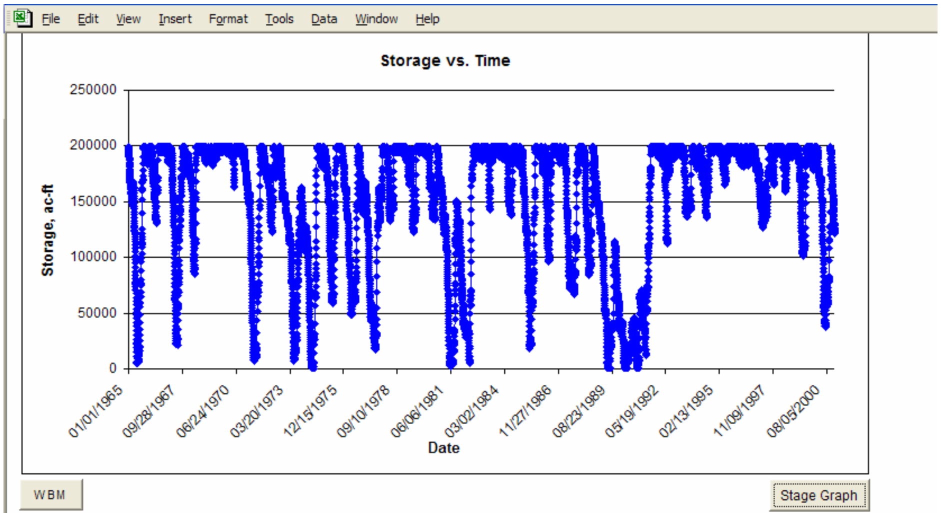
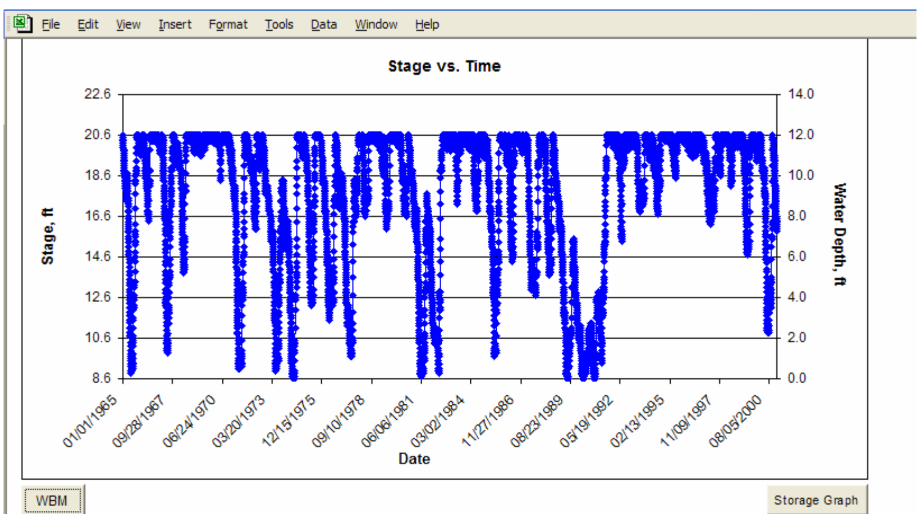


Figure 19 Storage versus Time from WBM Alternative 2



Summary Input:		Summary Output:	
Starting Conditions, Full / Empty	Full	Reservoir Target Volume, ac-ft	199169
Target Water Depth, ft	12.00	No. of Days Demands are Not Met (WSE <= 9.1 ft)	348
Reservoir Bottom Elevation, ft	8.60	Max. No. of Consecutive Days Demands are Not Met	68
North New River, Y / N	Y	No. of Months	2.3
Holeyland Distribution Canal, Y / N	Y	Year Occurring	1990
Irrigation Demands, %	100%		
Environmental Demands, %	100%		

Figure 20 Stage versus Time from WBM Alternative 2



Summary Input:		Summary Output:	
Starting Conditions, Full / Empty	Full	Reservoir Target WSE, ft	20.60
Target Water Depth, ft	12.00	Reservoir Minimum WSE, ft	9.10
Reservoir Bottom Elevation, ft	8.60	No. of Days Demands are Not Met (WSE <= 9.1 ft)	348
North New River, Y / N	Y	Max. No. of Consecutive Days Demands are Not Met	68
Holeyland Distribution Canal, Y / N	Y	No. of Months	2.3
Irrigation Demands, %	100%	Year Occurring	1990
Environmental Demands, %	100%	Target WSE, ft	18.60
Target Depth, ft	10.00	No. of Days Reservoir is over the Target Depth / WSE	12405

Figure 21 WBM Input and Output Screen for Alternative 3

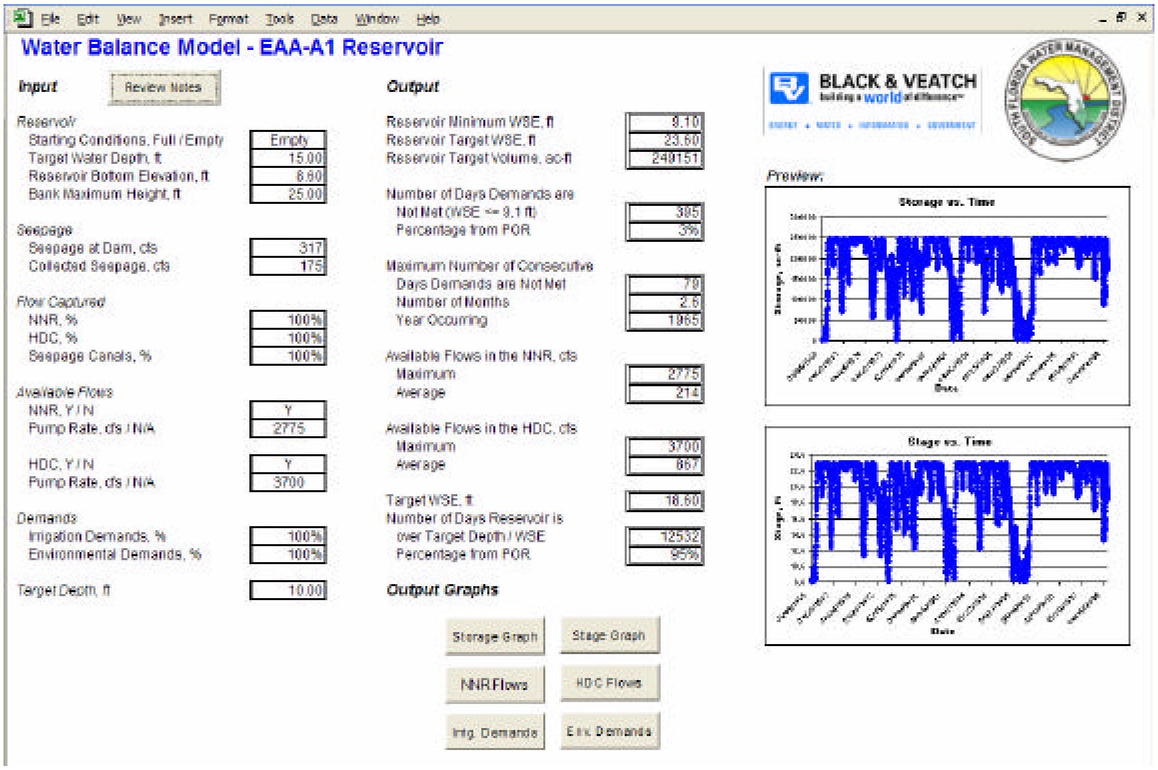


Figure 22 Storage versus Time from WBM Alternative 3

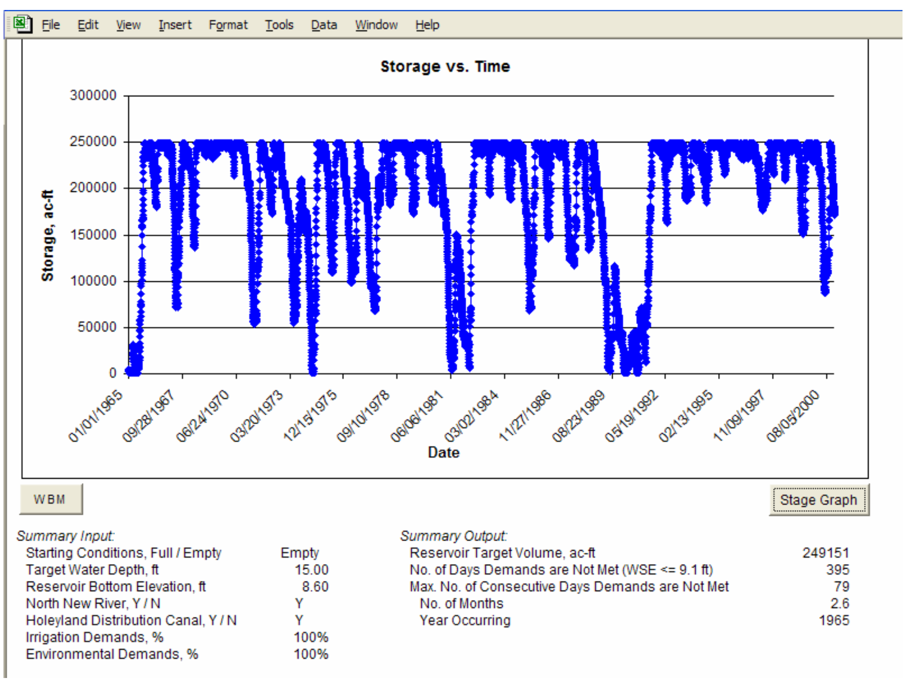


Figure 23 Stage versus Time from WBM Alternative 3

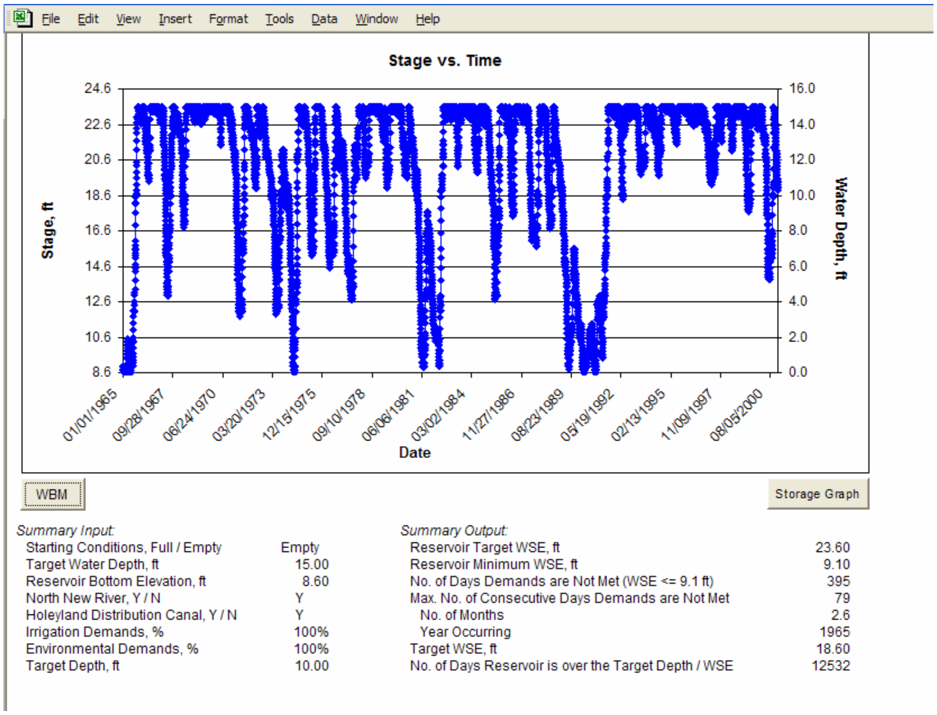


Figure 24 WBM Input and Output Screen for Alternative 4

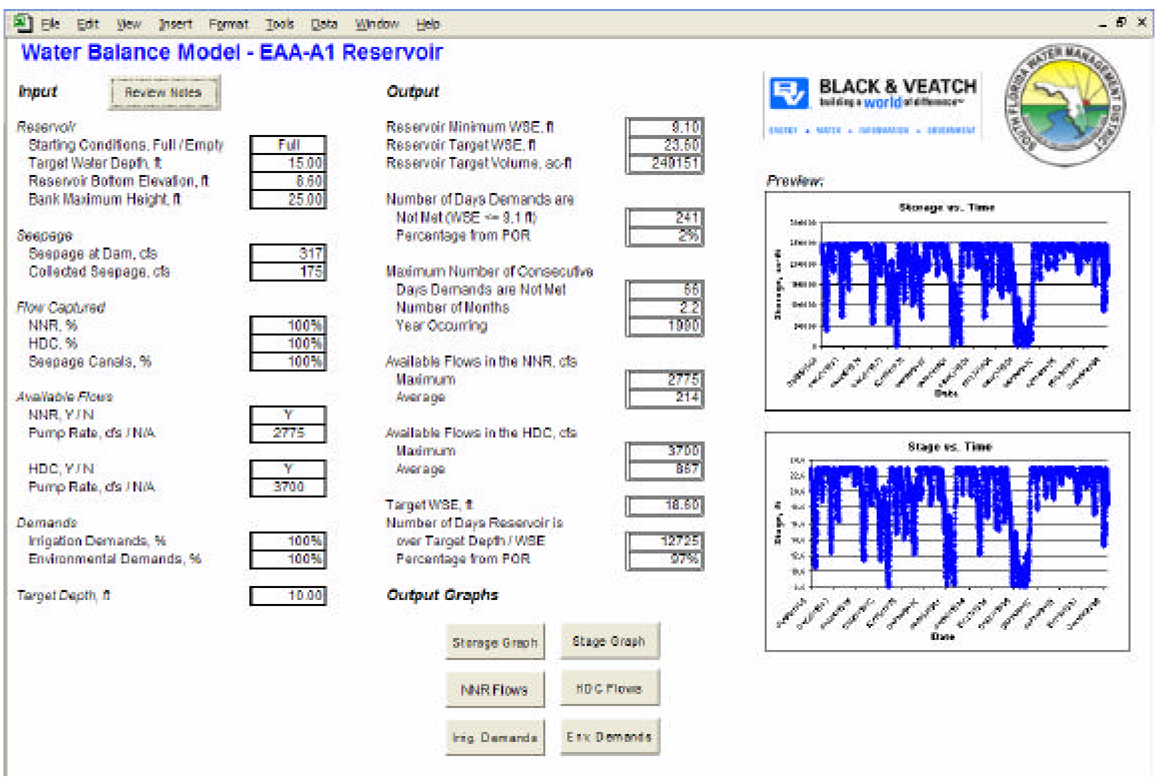
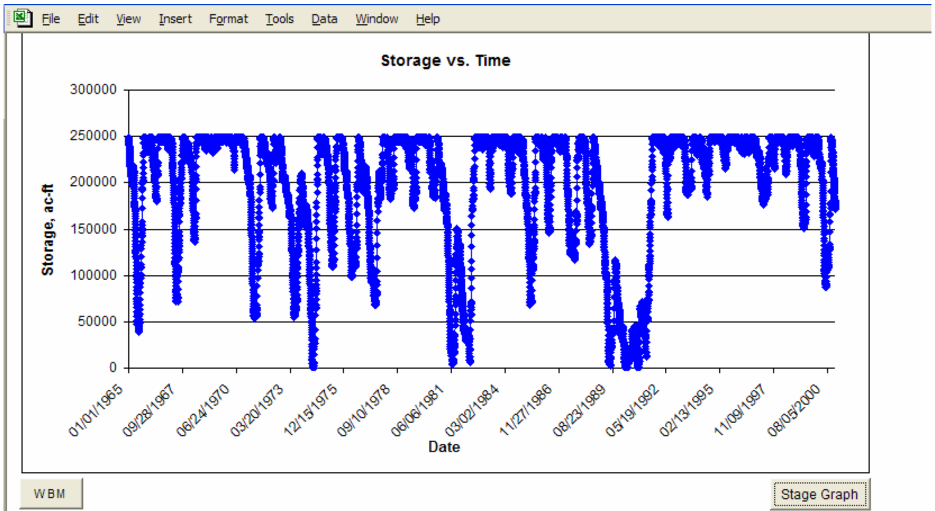
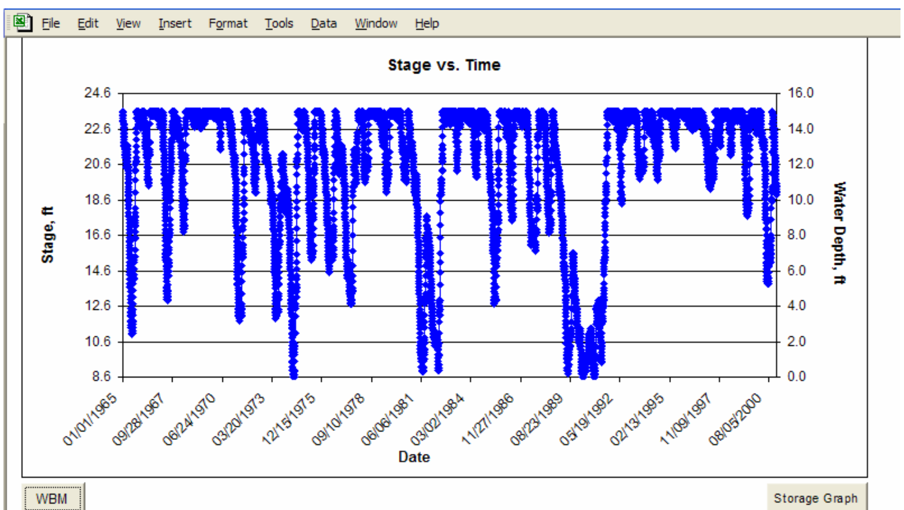


Figure 25 Storage versus Time from WBM Alternative 4



Summary Input:		*Summary Output:*	
Starting Conditions, Full / Empty	Full	Reservoir Target Volume, ac-ft	249151
Target Water Depth, ft	15.00	No. of Days Demands are Not Met (WSE <= 9.1 ft)	241
Reservoir Bottom Elevation, ft	8.60	Max. No. of Consecutive Days Demands are Not Met	66
North New River, Y / N	Y	No. of Months	2.2
Holeyland Distribution Canal, Y / N	Y	Year Occurring	1990
Irrigation Demands, %	100%		
Environmental Demands, %	100%		

Figure 26 Stage versus Time from WBM Alternative 4



Summary Input:		*Summary Output:*	
Starting Conditions, Full / Empty	Full	Reservoir Target WSE, ft	23.60
Target Water Depth, ft	15.00	Reservoir Minimum WSE, ft	9.10
Reservoir Bottom Elevation, ft	8.60	No. of Days Demands are Not Met (WSE <= 9.1 ft)	241
North New River, Y / N	Y	Max. No. of Consecutive Days Demands are Not Met	66
Holeyland Distribution Canal, Y / N	Y	No. of Months	2.2
Irrigation Demands, %	100%	Year Occurring	1990
Environmental Demands, %	100%	Target WSE, ft	18.60
Target Depth, ft	10.00	No. of Days Reservoir is over the Target Depth / WSE	12725